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(72) Inventor: **Morito, Hajime**
Minami Ward, Yokohama 232-0076 (JP)

(74) Representative:
Read, Matthew Charles et al
Venner Shipley & Co.
20 Little Britain
London EC1A 7DH (GB)

(71) Applicant:
HITACHI EUROPE LIMITED
Maidenhead, Berkshire, SL6 8YA (GB)

(54) **Copy protection apparatus and method**

(57) An apparatus and method of copy protection for use in digital data recorders such as DVD-RAM recorders (30), which includes using DVD disks (1) with unique serial numbers stored in a read only part (2) of the disk for recording data. The serial number of each disk together with other copy control information is digitally signed. The digital signature is verified at the DVD

player/recorder (13, 30) to check whether the disk being played is an original disk or an authorised copy. If not, play back and recording of the data on the disk is prevented. The use of copy control information also allows the implementation of a copy generation management system.

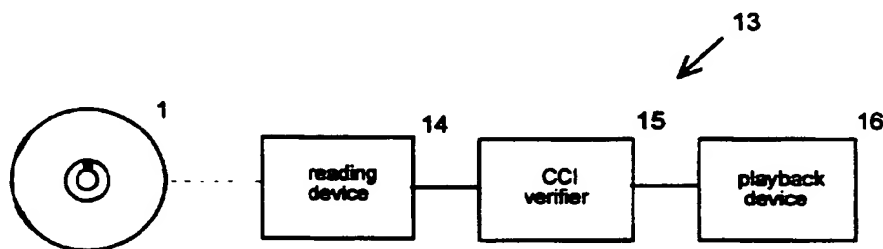


Figure 5

Description

[0001] This invention relates to copy protection, particularly but not exclusively to an apparatus and method for protecting digital data on a data storage medium from unauthorised copying.

[0002] Although digital media such as audio CDs and CD-ROMs allow perfect reproduction of digital data stored on them, the problems of controlling unauthorised reproduction have so far been mitigated to some extent by the fact that these media have generally only been available in a read-only format, so that the potential infringer needed specialist recording and CD-pressing equipment to make high quality copies.

[0003] However, the introduction into the consumer market of recordable digital storage technology, including CD-R (Write Once) and CD-RW (Rewritable), as well as Digital Versatile Disk (DVD) technology, which aims to make low cost digital recorders widely available, has raised the need for sophisticated copy protection systems, to prevent extensive piracy. It is envisaged that DVD recorders, known as DVD-RAM recorders, will eventually replace the various different forms of currently available storage equipment, including computer hard-disk drives and video cassette recorders.

[0004] The principles of DVD technology are well established, with DVD-RAM recorders such as the Hitachi GF-1000 series available on the market. Reference is directed to "DVD Demystified", by Jim Taylor, published by McGraw-Hill, 1998, for further information on DVD principles.

[0005] Without any form of copy control, films, audio recordings and other digital content distributed on DVD disk or CD-ROM, can be easily recorded by a DVD-RAM, or other digital recorder, onto a digital data storage medium such as a recordable DVD disk, from which they can be further copied numerous times onto other DVD disks, without any degradation in the copy quality.

[0006] To prevent unauthorised copying, devices sold to consumers incorporate copy protection mechanisms. For example, copy protection information can be embedded in the data sector of a DVD disk, as illustrated in "DVD Demystified", by Jim Taylor at page 128. A possible method of copy control using such embedded information is for the digital content provider to supply the film or other digital content on a read-only medium, for example a DVD-ROM disk, with a "Never-Copy" flag embedded in the data. The DVD player/recorder will check for the presence of this flag and, if an attempt is made to copy the disk when the flag is present, the recording circuitry will prevent recording. However, this type of protection can be circumvented by using DVD-ROM/RAM drives as peripherals for computers, so as to enable copying of the data from an original disk onto a recordable disk on a bit-by-bit basis, including the copy protection information.

[0007] To prevent such bypassing of the protection scheme, some DVD players are designed to check for

the presence of Never-Copy flags on recordable disks as opposed to ROM disks. The presence of such a flag on a recordable disk is taken to indicate that the disk is an unauthorised copy of an original ROM disk, so that playback of the data on the disk will be prevented. On the other hand, if the player detects that a ROM disk is being used, it will play back the data on the disk.

[0008] However, this scheme works on the premise that a computer user copying the disk will copy all of the data on a bit-by-bit basis, including the Never-Copy flag. The scheme can still be easily bypassed by the computer user who knows or determines where the copy control information is located on an original ROM disk, and who can therefore change or overwrite this information when making a copy of the original disk onto a recordable disk.

[0009] A further problem with the above described protection scheme is that it is inflexible, with no way of providing for a copy generation management system (CGMS), which governs the extent to which copying is permitted.

[0010] For example, there is no way of providing for the contents of an original data storage medium to be copied to a back-up medium, while preventing the production of a further generation of copies from the back-up medium.

[0011] The present invention aims to address the above problems.

[0012] According to the present invention, there is provided apparatus for processing data stored on a storage medium which has a medium identifier, the apparatus including means for controlling the processing of the stored data in dependence on the relationship between the medium identifier and verification information for the medium identifier stored on the medium.

[0013] The medium identifier may be a first medium identifier and the verification information can comprise a second medium identifier, so that the apparatus can prevent playback or recording if the first and second medium identifiers are different.

[0014] In the case of an original disk, the second medium identifier may be a copy of the first medium identifier.

[0015] The apparatus may include means for authenticating the verification information. The verification information may, for example, be digitally signed, and the authentication means may comprise means for verifying a digital signature.

[0016] The present invention further provides a method of processing data stored on a storage medium which has a medium identifier and verification information for the identifier stored on the medium, comprising controlling the processing of the stored data in dependence on the relationship between the medium identifier and the verification information.

[0017] The present invention also provides recording apparatus for recording data onto a data storage medium having a medium identifier, comprising means

for producing verification information for the medium identifier, said verification information to be stored on the medium.

[0018] The recording apparatus may include means for controlling recording onto the medium in response to copy control data stored on a medium from which the data is being recorded.

[0019] The present invention additionally provides a method of recording data onto a data storage medium having a medium identifier, comprising producing verification information for the medium identifier to be stored on the medium.

[0020] According to the present invention, there is further provided a data storage medium comprising a medium identifier and verification information for the identifier stored on the medium.

[0021] Advantageously, in accordance with the invention, digital data on a data storage medium can be protected from unauthorised copying even if the copy protection information in the data is falsified. In addition, the protection scheme provides for the generation of legitimate copies, such as backup copies.

[0022] Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a DVD disk according to the invention;

Figure 2 is a schematic block diagram of apparatus used to manufacture the disk of Figure 1;

Figure 3 is a schematic block diagram illustrating an example of the recording apparatus to be used by content providers to produce copy protected disks;

Figure 4 is a flow diagram illustrating the operation of the recording apparatus of Figure 3;

Figure 5 is a schematic block diagram of a DVD player according to the invention;

Figure 6 is a flow diagram illustrating the operation of the player of Figure 5;

Figure 7 is a flow diagram illustrating the detailed operation of the recording apparatus of Figure 3 and player of Figure 5 based on a given example of copy control information;

Figure 8 is a schematic block diagram of recording apparatus to be used by content providers according to a further example of the invention;

Figure 9 is a flow diagram illustrating the operation of the recording apparatus of Figure 8;

Figure 10 is a schematic block diagram of a data recording device according to the invention to be used in a consumer device;

Figure 11 is a flow diagram illustrating the operation of the recording apparatus of Figure 10;

Figure 12 is a flow diagram illustrating the detailed operation of the recording apparatus of Figure 8 for the case where copying of an original disk is not permitted;

Figure 13 is a flow diagram illustrating the detailed

operation of the player of Figure 5 where the disk being played is recorded in accordance with the recording operation illustrated in Figure 12;

Figure 14 is a flow diagram illustrating the detailed operation of the recording apparatus of Figure 8 for the case where one generation of copies from an original disk is permitted;

Figure 15 is a flow diagram illustrating the detailed operation of the player of Figure 5 where the disk being played is recorded in accordance with the recording operation illustrated in Figure 14;

Figure 16 is a flow diagram illustrating the detailed operation of the recording device of Figure 10 for the case where the data being recorded was itself recorded in accordance with the recording operation illustrated in Figure 14; and

Figure 17 is a flow diagram illustrating the detailed operation of the player of Figure 5 where the disk being played is recorded in accordance with the recording operation illustrated in Figure 16.

[0023] Referring to Figure 1, a DVD disk 1 according to the invention comprises an identification area 2 and a data area 3. The identification area is located on a read-only part of the disk, so that only the manufacturer of the disk can write information to this area during manufacture of the disk 1. For example, the identification area 2 can be the burst cutting area of a DVD disk, as further described in "DVD Demystified", by Jim Taylor, at pages 125 - 126.

[0024] Referring to Figure 2, a blank DVD disk 4 is first produced by conventional manufacturing steps by a medium generator 5. DVD media manufacturing processes are similar to those used to produce CD-R and CD-RW disks. A medium identifier generator 6, for example a computer running serial number generation software, produces a unique identifier, for example, a serial number, which is written to the burst cutting area 2 of the blank DVD disk 4 by a medium identifier printer 7 so as to produce the blank DVD disk 1 ready for data recording. The medium identifier printer 7 is, for example, a laser configured to cut a series of bar-code like stripes in the burst cutting area 2 to represent the serial number. While, in practice, the identifier may well be unique, this is not an essential requirement, the criterion being that, to prevent extensive copying, it should be sufficiently unlikely that a consumer will be readily able to obtain disks having the same identification number.

[0025] The accessibility of the data area 3 of the DVD disk 1 depends on the type of disk involved. In the case of a DVD-ROM disk, this area is read-only. A DVD-ROM disk can be produced by stamping it from a master copy, as described in "DVD Demystified", by Jim Taylor, at pages 121 - 123. This is the most cost-effective process when producing a very large number of disks. Other manufacturing techniques for DVD-ROM disks enable the incorporation of unique data onto each individual disk.

[0026] In the case of a DVD-R (Write-Once) disk, the manufacturer produces a blank disk which includes, for example, a unique serial number in the identification area 2. The data area 3 is however available to be written to, once only, by the content provider, using conventional data writing apparatus. Once the content provider has written data to the disk, it essentially behaves as a DVD-ROM, and cannot be rewritten by the consumer.

[0027] Alternatively, the disk 1 may be a DVD-RAM (Rewritable) disk, typically distributed as a blank disk for recording and re-recording by consumers.

[0028] The principles behind the production of a pre-recorded disk for distribution to consumers are illustrated below by reference to a DVD-R disk 1, for example produced by the manufacturing arrangement illustrated in Figure 2, as a result of which the content provider receives blank disks from the disk manufacturer, each having a unique disk identifier, for example, a serial number, written in the identification area 2 at the manufacturing stage. The content provider can then record a film, audio data or other digital content, generically referred to herein as data, and other relevant information to the disk 1, as explained by reference to the recording apparatus 8 illustrated in Figure 3.

[0029] One example of the recording apparatus 8 to be used by the content provider comprises a reading device 9 for reading the disk identifier from the read-only part 2 of the DVD disk 1, a copy control information (CCI) generator 10 and a recording module 11 for recording the generated copy control information together with the data from a data archive 12 onto the disk 1.

[0030] Referring to Figure 4, which describes the operation of the recording apparatus 8, at step s1, the reading device 9 reads the disk identifier from the disk 1 being recorded and passes the identifier to the CCI generator 10, which produces verification information for the disk identifier in the form of copy control information (s2). At step s3, the recording module 11 reads the data from the data archive 12 and records this onto the disk 1 together with the copy control information from the CCI generator 10 (s4). The resulting pre-recorded disk 1 is referred to herein as the original disk.

[0031] Referring to Figure 5, a DVD player 13 according to the invention comprises a reading device 14, a CCI verifier module 15 and a playback device 16. Referring to Figure 6, which describes the operation of the player 13, at step s5, the reading device 14 reads the data, copy control information and the disk identifier from the disk 1 being played and sends this information to the CCI verifier module 15. At step s6, the verifier module 15 attempts to verify the copy control information, namely to determine from the copy control information and the disk identifier whether the disk being played is an original disk, an authorised copy or an unauthorised copy. If verification is successful, control passes to step s7 and the playback device 16 plays back the data. If verification is unsuccessful, control passes to step s8

and playback is prevented, since failure of the verification process is taken to mean that the disk being read is an unauthorised copy.

[0032] In all of the examples of the invention described herein, devices required to read and write data to DVD disks, such as the recording module 11, reading devices 9, 14 and the playback device 16, can be implemented by conventional circuitry as currently used in commercially available DVD player/recorders such as the Hitachi GF-1000 series. The functionality of the blocks required to implement the invention, such as the CCI generator 10 and CCI verifier 15 can be implemented in software on conventional microprocessor based circuitry.

[0033] One example of the copy control information which can be recorded onto the disk 1 is simply a copy of the original disk identifier read by the reading device 9 in the recording apparatus 8. Referring to Figure 7, at step s9, the reading device 9 reads a disk identifier S_d from the original disk and at step s10 stores S_d as the copy control information. At step s11 the recording module 11 reads data from the data archive 12 and then records the data and S_d to the data area 3 of the disk 1 (s12). At step s13, the reading device 14 in the player 13 reads S_p , the disk identifier of the disk being played, from the burst cutting area 2 of the disk 1 and sends it to the CCI verifier 15. It also reads the copy control information, namely S_d , from the data area 3 of the disk 1. At step s14, the CCI verifier 15 compares the actual disk identifier S_p with the copy of the original disk identifier S_d . If the original disk has not been copied, the two identifiers, for example the serial number of each disk, will be identical and a signal will be sent to the playback device 16 (s15) indicating that the disk can be played. On the other hand, if the original disk has been copied, so that all the data on it has been transferred to a new disk, then the disk identifier S_p in the burst cutting area 2 of the new disk will be different from the original disk identifier S_d copied over to the data area 3 of the new disk. In this case, a signal is sent to the playback device 16 (s16) that the disk is an unauthorised copy and therefore cannot be played.

[0034] The use of a copy of the original disk identifier as the copy control information provides a form of playback copy control similar to the use of a Never-Copy flag as described above. Therefore, while the making of a copy of an original disk is not itself prevented, a DVD player according to this example will not play back the data on the copy. Furthermore, the making of a second generation of copies from the copied disk can itself be prevented by a recording device which provides the same verification check as the player 13, as illustrated at steps s14 to s16. This works because the recording device recognises a first generation copy as one in which $S_p \neq S_d$ and so can prevent further recording.

[0035] To prevent a consumer from bypassing the protection provided by the copy control method described above, it is envisaged that the copy control information

should itself be protected against access and alteration.

[0036] An example of a suitable form of protection is the use of a digital signature, which can be based on a public key cryptographic system. Methods of forming digital signatures are well-known and digital signature software is commercially available, for example from RSA Data Security Inc, California, USA, which uses the well-known RSA public-key algorithm. The principles of public key systems and their use in digital signatures are set out below. For a more detailed description, reference is directed to Bruce Schneier, "Applied Cryptography", John Wiley & Sons, Inc. 1996, ISBN 0-471-11709-9.

[0037] Public key encryption is based on the use of an asymmetric pair of mutually inverse mathematical operations known as a key pair.

[0038] For example, assuming that E is a public key algorithm, then the notation $E_K(m)$ signifies the encryption of a message m using a key K.

[0039] If K and K^{-1} are key pairs for E, then $E_{K^{-1}}(E_K(m)) = m$. So a message encrypted with a key K^{-1} , referred to herein as the private key, can be decrypted by applying the key K, referred to herein as the public key. Public key cryptography is based on the fact that it is currently not computationally feasible to calculate one part of the key pair from the other part if the bit length of the key is large enough, for example 512 bits or larger.

[0040] A digital signature can be based on a public key algorithm and a one way hash function. A hash function is any function which takes a variable-length input string and converts it to a fixed-length and generally smaller output string known as the hash value. A one way hash function is a function for which, given a message m, it is easy to calculate a hash value $c = H(m)$, but for which it is difficult to calculate m, starting from a given hash value c. It is generally computationally unfeasible to calculate m from c if the output bit length of H is large enough, for example 128 bits or larger. Reference is further directed to Bruce Schneier, "Applied Cryptography", pages 29 to 31 and 38 to 39, and to D.W. Davies and W.L. Price, "The Application of Digital Signatures Based on Public-Key Cryptosystems", Proceedings of the Fifth International Computer Communications Conference, October 1980, pp. 525 - 530 and National Physical Laboratory Report DNACS 39/80, December 1980.

[0041] The way in which a digital signature can be used is illustrated below.

[0042] For example, X wishes to send a message to Y. We assume that the content of the message is not secret, but that Y wishes to be sure that the message originated from X and that it is unaltered by any third party. Therefore, X generates key pairs K and K^{-1} for public key algorithm E. X keeps the private key K^{-1} secret and opens key K to the public. Then X generates the message m and signs it digitally, by:

1. calculating $c = H(m)$, where H is a known hash function
2. encrypting c by E using private key K^{-1} ie. digital signature = $E_{K^{-1}}(c)$

[0043] The digital signature is referred to herein as

$$\text{Sig}_{K^{-1}}(m),$$

so that the above equation can be written as $\text{Sig}_{K^{-1}}(m) = E_{K^{-1}}(c)$

[0044] When Y receives the message m, he can verify the digital signature using X's public key K, by:

1. calculating $c' = H(m)$
2. decrypting

$$E_{K^{-1}}(c)$$

using key K to obtain c, ie. $c = E_K(E_{K^{-1}}(c))$

3. comparing c and c'

[0045] If $c = c'$, the verification succeeds, otherwise it fails.

[0046] The verification will fail if the message m has been changed in any way, since in that case the hash of the message c' will change. Alternatively, the verification will fail if the digital signature has been falsified. Since X is the only person who has access to the private key K^{-1} , X is the only person capable of generating the correct digital signature which can be verified by the public key K.

[0047] Referring again to Figure 3, to apply the above described form of protection in the simple case outlined above of using a copy of the original disk identifier to verify the authenticity of a disk being played, the CCI generator 10 in the recording apparatus 8 includes an input from a key pair generator which generates a key pair K, K^{-1} . Key pair generator software, including generators for specific algorithms such as the DSA and RSA algorithms, is widely available commercially, and can, for example, be implemented in the Java™ programming language. The Java™ API, for example, includes a key pair generator class known as `java.security.KeyPairGenerator`. A disk identifier S_d , where S_d represents the disk identifier of the original disk, is read from the disk 1 by the reading device 9 and a digital signature

$$\text{Sig}_{K^{-1}}(S_d)$$

is formed using the private key K^{-1} and a suitable one-way hash function $H(x)$ which is fixed at both the recording apparatus and the player.

[0048] An example of a suitable hash function is the

Secure Hash Algorithm (SHA) described at pages 442 - 445, "Applied Cryptography", referred to above. This algorithm accepts a variable length input bit stream and outputs a 160 bit hash. Typically, knowledge of the hash function decided on will be limited to the recording apparatus/player equipment vendors on the basis of a non-disclosure agreement. The digital signature

$$\text{Sig}_{K^{-1}}(S_d)$$

is recorded onto the disk 1 by the recording module 11 together with the public key K.

[0049] Referring again to Figure 5, at the player 13, the reading device 14 reads the public key K and

$$\text{Sig}_{K^{-1}}(S_d)$$

from the data area 3 and the disk identifier S_p from the identifier area 2 of the disk 1 being played. The CCI verifier 15 calculates the hash value $H(S_p)$ and uses K to decrypt

$$\text{Sig}_{K^{-1}}(S_d)$$

so as to obtain the hash value $H(S_d)$. It then compares these two hash values. If S_n and S_p are identical, because the disk being played is the original disk, then the hash values are also identical, then verification is successful and a signal is sent to the playback device 16 permitting playback. If S_d and S_p are not identical, because the disk being played is a copy of the original disk, then their hash values will be different, so that the verification process fails, which triggers a signal to the playback device 16 to prevent playback.

Since the content provider is the only one to have access to the private key K^{-1} , it is the only one that can correctly encrypt the serial number or other identifier of the original disk.

[0050] To permit more complex control over copying, further information can be included as part of the copy control information, for example, a copy control field which is capable of implementing copy generation management.

[0051] Figures 8 and 9 explain the general structure of another example of a recording apparatus 20 for use by a content provider and the steps involved in the production of a pre-recorded copy protected disk.

[0052] At step s17, a key pairs generator module 21 generates key pairs of the public algorithm for signature verification. At step s18, a reading device 22 reads the identifier of the DVD disk 1, for example a serial number, from the read-only part 2 of the disk 1. At step s19, a copy control information (CCI) generator 23 produces copy control information including a digital signature on the basis of the keys, identifier and a copy control field

from a copy control field (CCF) database 24. The copy control field can take one of at least four values, including Copy-Freely, Never-Copy, Copy-Once and No-More-Copy. The actual information which goes to make up the copy control information will be explained in more detail below. At step s20, a recording module 25 reads the data to be written to the DVD disk 1 from a data archive 26 and at step s21, writes the data and the copy control information from the CCI generator 23 to the DVD disk 1 to produce the finished copy protected pre-recorded DVD disk.

[0053] The general structure and functionality of a DVD player has already been described by reference to Figures 5 and 6.

[0054] Figure 10 illustrates the structure of a recording device 30 in accordance with the invention for use by consumers to record data onto recordable disks. Referring to Figures 10 and 11, at step s22, the input signal processor module 31 receives copy control information and data to be recorded from a disk player 13 as described above, and sends them to a CCI verifier module 32 and a CCI generator 33. At step s23, the CCI verifier 32 attempts to verify the copy control information. The CCI verifier 32 performs the same verification function as the CCI verifier 15 in the player 13, and if the player and recording device are implemented as a single unit, the verifier 32 is implemented by the same circuitry or by the same software function. If, however, the recording device 30 is a separate unit from the player 13, the CCI verifier 32 is implemented as a double checking facility and to provide a verification function for a player which may not include copy protection facilities.

[0055] If verification fails at this stage (s23), control passes to step s29, and recording of the data onto a new disk is prevented. If verification succeeds, then control passes to step s24, at which the CCI verifier 32 determines if the copy control field indicates that the data can be freely copied, for example, because of the presence of a Copy-Freely flag. If the data can be freely copied, control passes to step s28, at which the recording module 34 records the copy control information and the data to a new disk 35. If, at step s24, the copy control information indicates that data cannot be freely copied, control passes to step s25, at which the CCI verifier 32 determines if the copy control field indicates that the data can be copied only once, for example, because of the presence of a Copy-Once flag. If the flag is not a Copy-Once flag, the conclusion is that a Never-Copy or No-More-Copy flag is set, and control also passes to step s29 where recording is prevented. If, on the other hand, at step s25, the copy control information indicates that the Copy-Once flag is set, control passes to step s26, at which the reading device 36 reads the medium identifier of the new disk 35 from the read-only part of that disk and sends this identifier to the CCI generator 33. At step s27, the CCI generator changes the copy control field from Copy-Once to Copy-No-More and generates new copy control information to be recorded

onto the disk 35 by the recording module 34. The nature of the new copy control information is explained in detail below.

[0056] The precise nature of the copy control information which is written to an original disk depends on the level of protection which a content provider wishes to achieve. For example, the provider may decide that the content of, for example, its DVD-audio disk can never be copied. On the other hand, the provider may wish to provide its customers with the ability to make a back-up copy of the original, but not to produce further copies. The way in which these goals can be achieved is explained below using the following notation:

[0057] ID is information identifying the content provider. This can include the provider's name, the name of the content, its date of production and so on. CCF represents the copy control field, which can take the values Copy-Freely, Never-Copy, Copy-Once and No-More-Copy, as explained above. A and A' are used as convenient notation to group the provider dependent information ID and CCF together, for example, by concatenation, such that $A = ID : CCF$ and $A' = ID : CCF'$, where CCF' represents a change in the value of the copy control field when recording onto a new disk. S_d, S_c and S_p are disk identifiers printed on the read-only part of the disk. They cannot therefore be changed by the consumer. S_d represents the disk identifier of the original disk, S_c represents the disk identifier of the disk to which the original disk can be legitimately copied and S_p represents the disk identifier of the disk being played. It will be understood that S_p can take the values of S_d and S_c where, respectively, the original disk and a legitimate copy of the original disk, are being played. K_A and

$$K_{A^{-1}}$$

are key pairs for the digital signature of the content provider. K_M and

$$K_{M^{-1}}$$

are key pairs for the digital signature required to implement the CGMS scheme, for example to ensure that a copy is only made from the original and not from a copy of the original.

[0058] Referring to Figures 8 and 12, in the case where a content provider wishes to prohibit all copying from the original disk, including the making of a backup copy, at step s30, the CCF flag is set to Never-Copy. At step s31, the key pairs generator module 21 generates key pairs K_A and

$$K_{A^{-1}},$$

as described above for the first example. The reading device 22 then reads S_d from the read-only part of the disk 1 (s32) and the CCI generator 23 calculates the digital signature

$$\text{Sig}_{K_{A^{-1}}}(S_d, A)$$

at step s33. The copy control information in this case comprises

$$\text{Sig}_{K_{A^{-1}}}(S_d, A),$$

A and K_A . The recording module 25 then reads data from the data archive 26 (s34) and at step s35 writes the data to the disk 1 together with the copy control information from the CCI generator 23.

[0059] Referring to Figures 5 and 13, when a DVD disk 1 encoded with the above data is inserted into a DVD player 13, at step s40 the reading device 14 reads S_p from the read-only part 2 of the disk 1. It also reads the copy control information, namely A, K_A and

$$\text{Sig}_{K_{A^{-1}}}(S_d, A),$$

from the data area 3. The CCI verifier 15 then verifies the digital signature

$$\text{Sig}_{K_{A^{-1}}}(S_d, A)$$

using S_d , A and K_A at step s41. If the verification succeeds, control passes to step s42 and the data is played back. Otherwise, control passes to step s43, where playback of data is prevented. To further explain the operation of this example, the verification process is explained in detail below.

[0060] Knowing S_p read from the identification area 2 of the disk and A read from the data area 3 of the disk 1, it is possible to calculate a function c' using a one-way hash function H, such that $c' = H(m)$, where $m = (S_p, A)$. Therefore, $c' = H(S_p, A)$.

[0061] The function H is the same function as was used at the recording apparatus 20 to produce a function $c = H(S_d, A)$. This function is obtained by decrypting

$$\text{Sig}_{K_{A^{-1}}}(S_d, A)$$

using the public key K_A read from the data area 3 of the disk 1.

[0062] If $c = c'$, i.e. $H(S_d, A) = H(S_p, A)$, this verifies that both A and S_p are unchanged from the time of recording, and in particular that $S_p = S_d$, namely that the serial number on the disk being played is identical to

the serial number of the disk on which the data was recorded. On the assumption that the serial numbers are unique, this means that the disk being played is the original disk and so playback of the data it contains is permitted. If the verification fails, the disk being played is assumed to be a copy and playback is therefore prevented.

[0063] Referring to Figures 8 and 14, in the case where a content provider wishes to provide the facility for the making of a backup copy from the original disk only, step s50 is to set the Copy Control Field to Copy-Once. At step s51, the key pairs generator module 21 generates key pairs K_A and K_A^{-1} , as well as K_M and K_M^{-1} . The reading device 22 then reads S_d from the read-only part of the disk 1 (s52) and the CCI generator 23 calculates the digital signature

$$\text{Sig}_{K_A^{-1}}(S_d, A, K_M)$$

at step s53. The recording module 25 then reads data from the data archive 26 (s54) and at step s55 writes the data to the disk 1 together with the copy control information from the CCI generator 23, which comprises A , K_A , K_M , K_M^{-1} and

$$\text{Sig}_{K_A^{-1}}(S_d, A, K_M).$$

[0064] Referring to Figures 5 and 15, when a DVD disk 1, encoded with the above data, is inserted into a DVD player 13, at step s60, the reading device 14 reads S_p from the read-only part 2 of the disk 1. It also reads the copy control information, namely A , K_A , K_M , K_M^{-1} and

$$\text{Sig}_{K_A^{-1}}(S_d, A, K_M)$$

from the data area 3 of the disk 1. The CCI verifier module 15 then verifies the digital signature

$$\text{Sig}_{K_A^{-1}}(S_d, A, K_M)$$

using S_d , A , K_M and K_A (step s61) as explained in detail above. If the verification succeeds, control passes to step s62 and the data is played back. Otherwise, control passes to step s63, where playback of data is prevented.

[0065] Since it is permitted to make a backup copy of the original disk, the detailed operation of the recording device 30 shown in Figure 10, is set out in the flowchart of Figure 16. Referring also to Figures 10 and 15, steps s70 and s71 are identical to steps s60 and s61 as carried out by the playback device. If the verification procedure fails, all further processing is stopped at step s72.

The purpose of including K_M in the verification procedure is to ensure that K_M has not been falsified, since both parts of the key pair K_M

$$K_M^{-1}$$

and are included, and therefore available to a potential infringer, on the original disk. If the verification procedure succeeds, then at step s73, the reading device 36 reads S_c from the read-only part of the destination disk 35. The CCI generator 33 changes the copy control field of A from Copy-Once to No-More-Copy and stores it as A' (s74). It then calculates the digital signature

$$\text{Sig}_{K_M^{-1}}(S_c, A')$$

(s75) and at step s76 writes S_d , A , K_M , K_A ,

$$\text{Sig}_{K_A^{-1}}(S_d, A, K_M),$$

A' and

$$\text{Sig}_{K_M^{-1}}$$

(S_c , A') to the data area 3 of the destination disk 35.

[0066] Referring to Figures 5 and 17, to play back data from a disk which is marked with a No-More-Copy flag, at step s80 the reading device 14 reads S_p from the read-only part 2 of the disk 35. It also reads the copy control information, namely S_d , A , K_M , K_A ,

$$\text{Sig}_{K_A^{-1}}(S_d, A, K_M),$$

A' and

$$\text{Sig}_{K_M^{-1}}(S_c, A')$$

from the data area 3 of the disk (s81). The CCI verifier 15 then verifies the digital signature

$$\text{Sig}_{K_A^{-1}}(S_d, A, K_M)$$

using S_d , A , K_M (s82). This step verifies that the key K_M used in the second part of the verification process has not itself been falsified. If verification fails, playback is stopped (step s85). If verification succeeds, then at step s83, the CCI verifier module 15 verifies the second digital signature

$$\text{Sig}_{K_M^{-1}}(S_c, A')$$

using S_p , A' and K_M . If $S_p = S_c$, then this step verifies that the copied disk has not itself been copied, so preventing playback of second generation copies. If verification succeeds the playback device 17 plays back the data (s84), otherwise play back is prevented (s85).

[0067] It will be appreciated that the method according to the invention can be used in any general digital recording system where a unique or nearly unique identifier can be associated with a storage medium. This includes, for example, smart card RAM memories with some ROM memory for immutable storage of the identifier.

[0068] It will further be appreciated that although a scheme based on the public key algorithm has been described in detail, other means of implementing a digital signature are not excluded.

Claims

1. Apparatus for processing data stored on a storage medium which has a medium identifier, the apparatus including means for controlling the processing of the stored data in dependence on the relationship between the medium identifier and verification information for the medium identifier stored on the medium.
2. Apparatus according to claim 1, wherein the medium identifier is stored on a read-only part of the medium.
3. Apparatus according to claim 1 or 2, wherein the medium identifier comprises a first medium identifier and the verification information includes a second medium identifier.
4. Apparatus according to claim 3, wherein the controlling means is responsive to a comparison between the first medium identifier and the second medium identifier.
5. Apparatus according to claim 4, wherein the controlling means prevents playback of the data if the first and second medium identifiers are different.
6. Apparatus according to claim 4 or 5, wherein the controlling means prevents recording of the data if the first and second medium identifiers are different.
7. Apparatus according to any preceding claim, further comprising means for authenticating the verification information.
8. Apparatus according to claim 7, wherein the verification information is digitally signed, and the authentication means comprises means for verifying a digital signature.
9. Apparatus according to any preceding claim, further comprising means for controlling the recording of data from the medium.
10. Apparatus according to claim 9, wherein the recording control means is responsive to copy control data stored on the medium.
11. Apparatus according to claim 10, wherein the copy control data specifies that the medium can be copied freely, copied once or cannot be copied.
12. Apparatus according to claim 10 or 11, wherein the copy control data is digitally signed.
13. Apparatus according to any preceding claim comprising a DVD player.
14. Apparatus according to claim 13, wherein the medium comprises a DVD disk.
15. A method of processing data stored on a storage medium which has a medium identifier and verification information for the identifier stored on the medium, comprising controlling the processing of the stored data in dependence on the relationship between the medium identifier and the verification information.
16. Recording apparatus for recording data onto a data storage medium having a medium identifier, comprising means for producing verification information for the medium identifier, said verification information to be stored on the medium.
17. Apparatus according to claim 16, including means for digitally signing the verification information.
18. Apparatus according to claim 16 or 17, wherein the verification information comprises the medium identifier.
19. Apparatus according to any one of claims 16 to 18 including means for controlling recording onto the medium in response to copy control data stored on a medium from which the data is being recorded.
20. A method of recording data onto a data storage medium having a medium identifier, comprising producing verification information for the medium identifier to be stored on the medium.
21. A method according to claim 20, comprising read-

ing the medium identifier from a read only part of the medium.

22. A method according to claim 20 or 21, comprising protecting the verification information using a digital signature. 5
23. A data storage medium comprising a medium identifier and verification information for the identifier stored on the medium. 10

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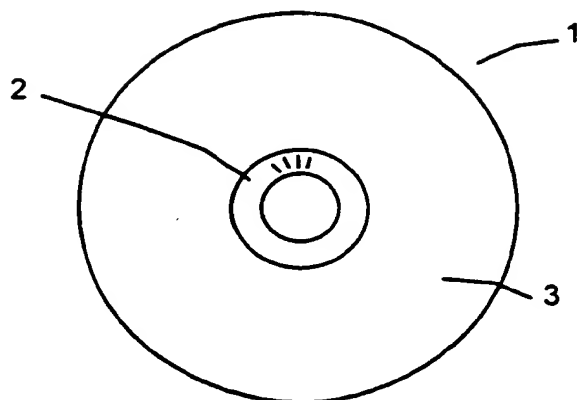


Figure 1

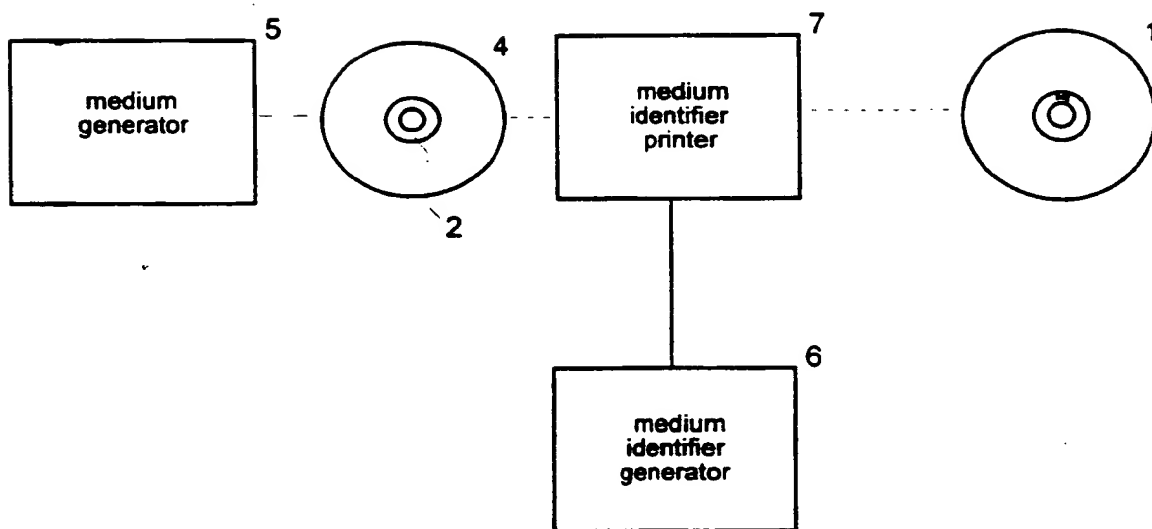


Figure 2

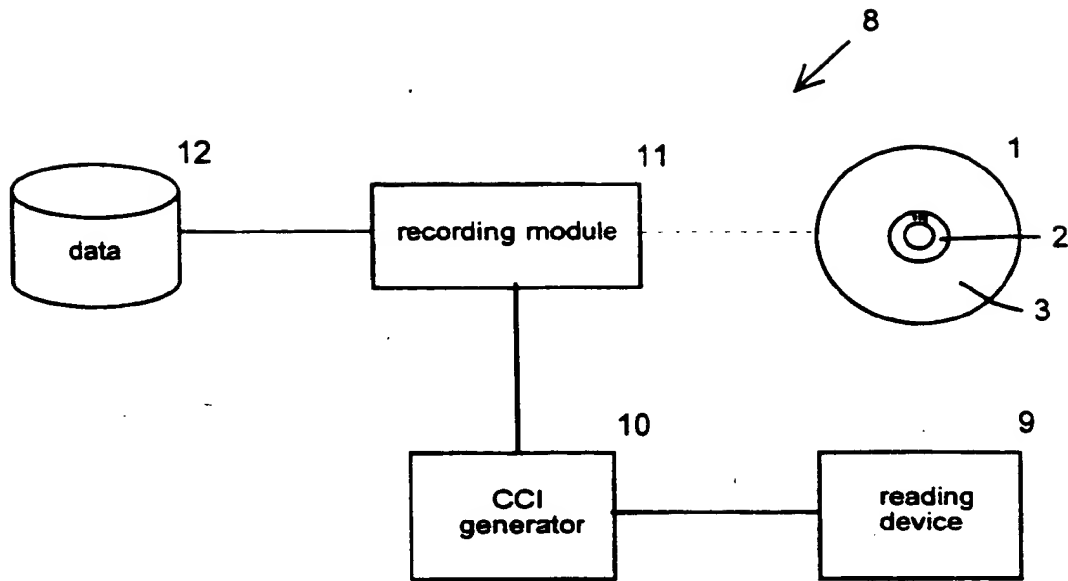


Figure 3

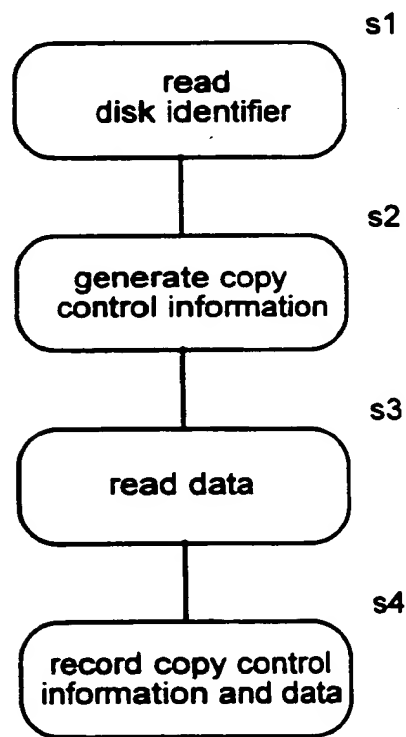


Figure 4

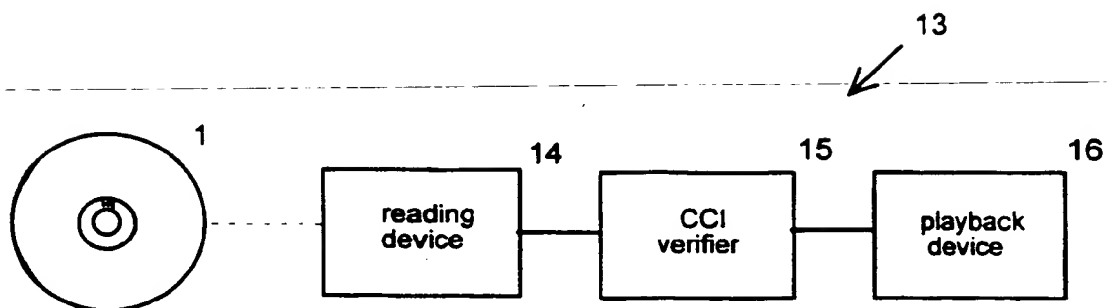


Figure 5

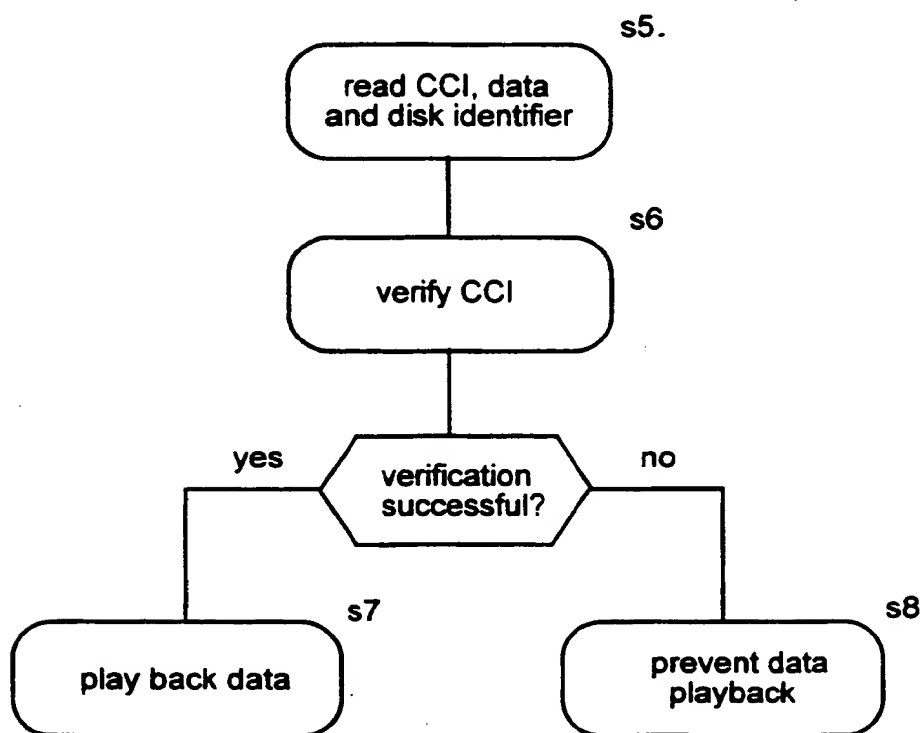


Figure 6

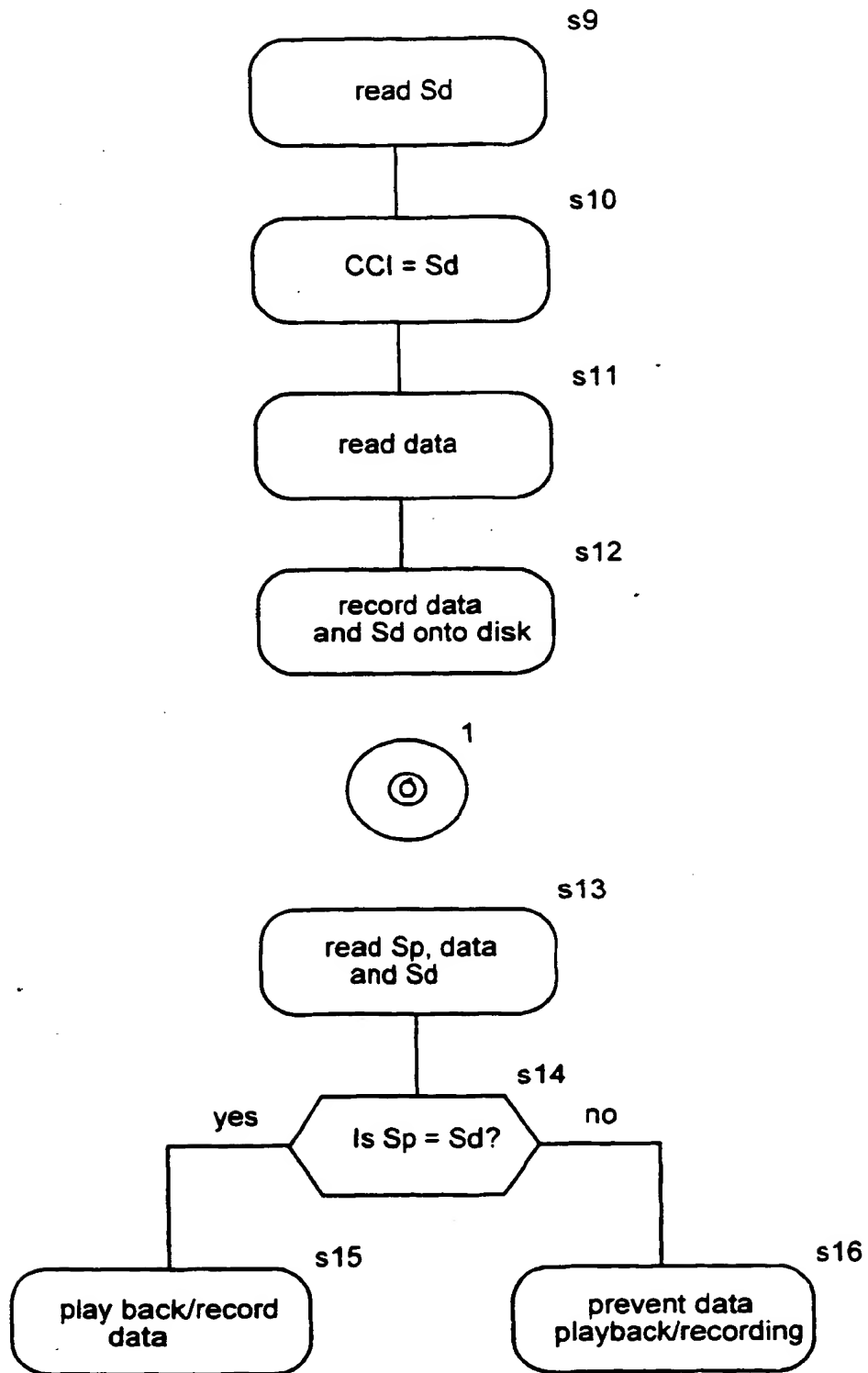


Figure 7

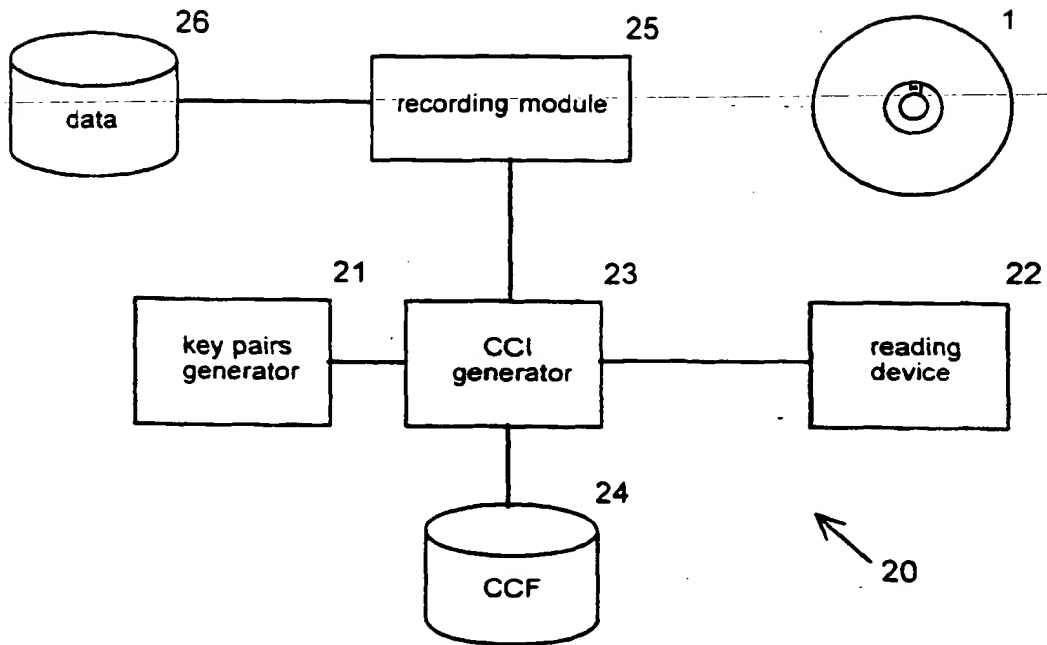


Figure 8

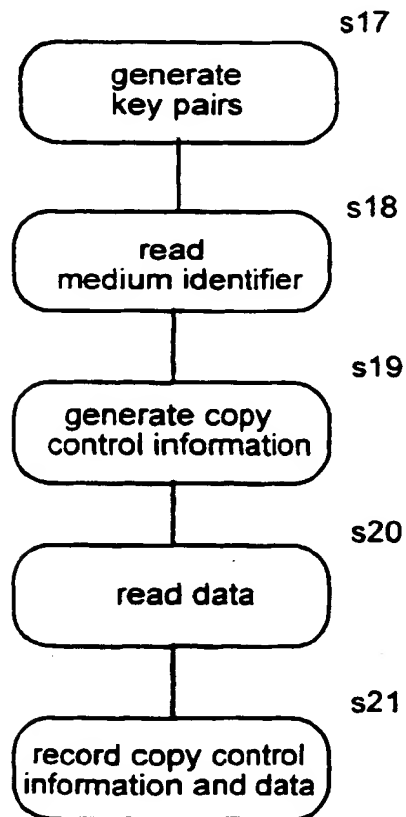


Figure 9

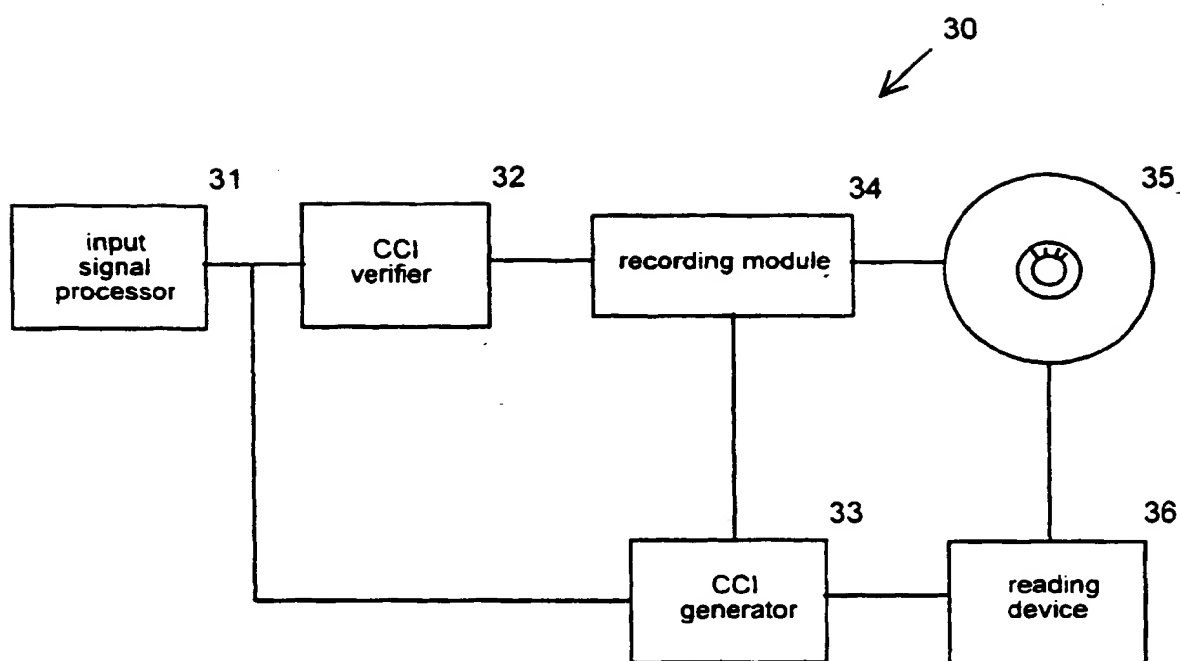


Figure 10

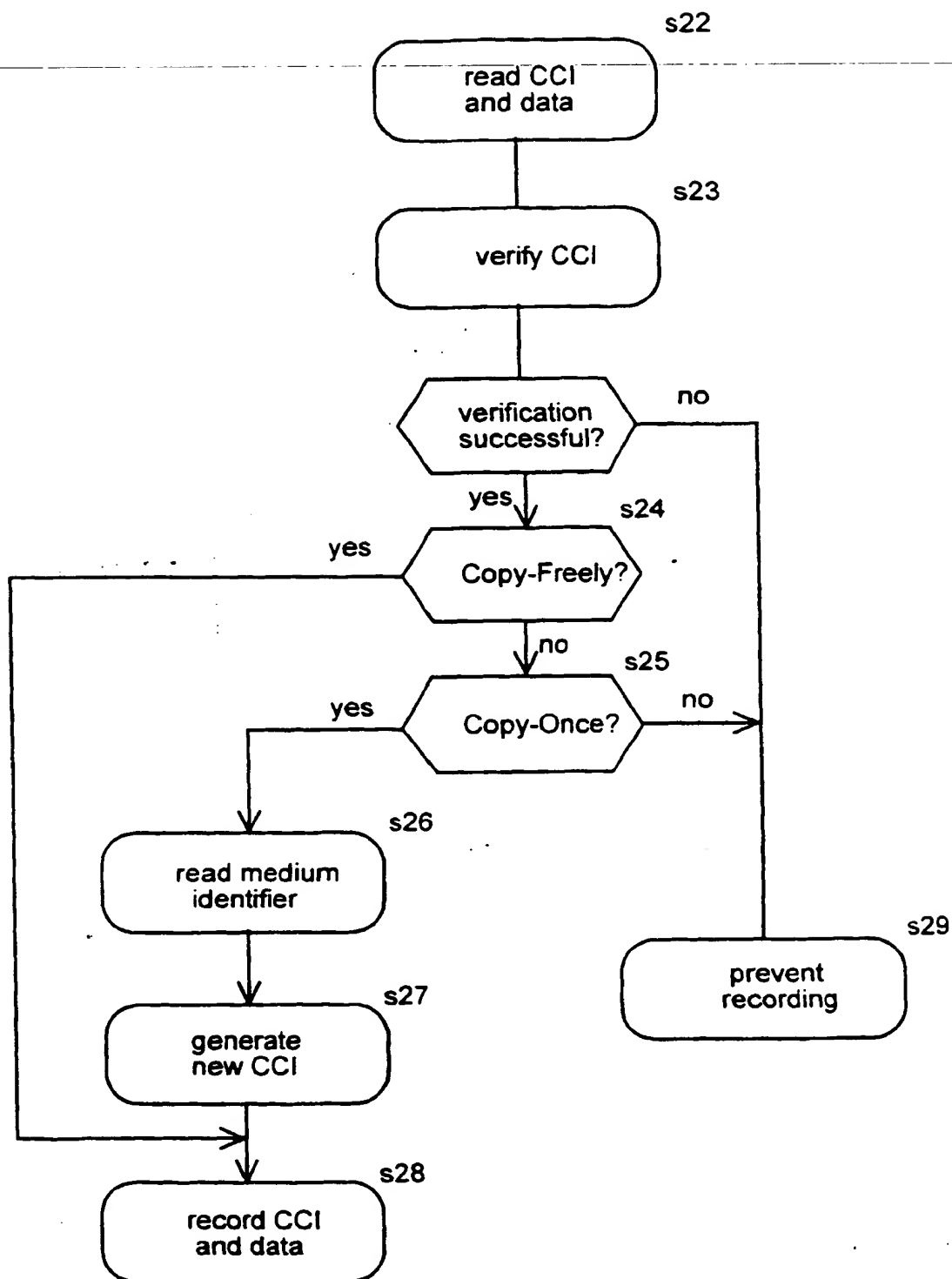


Figure 11

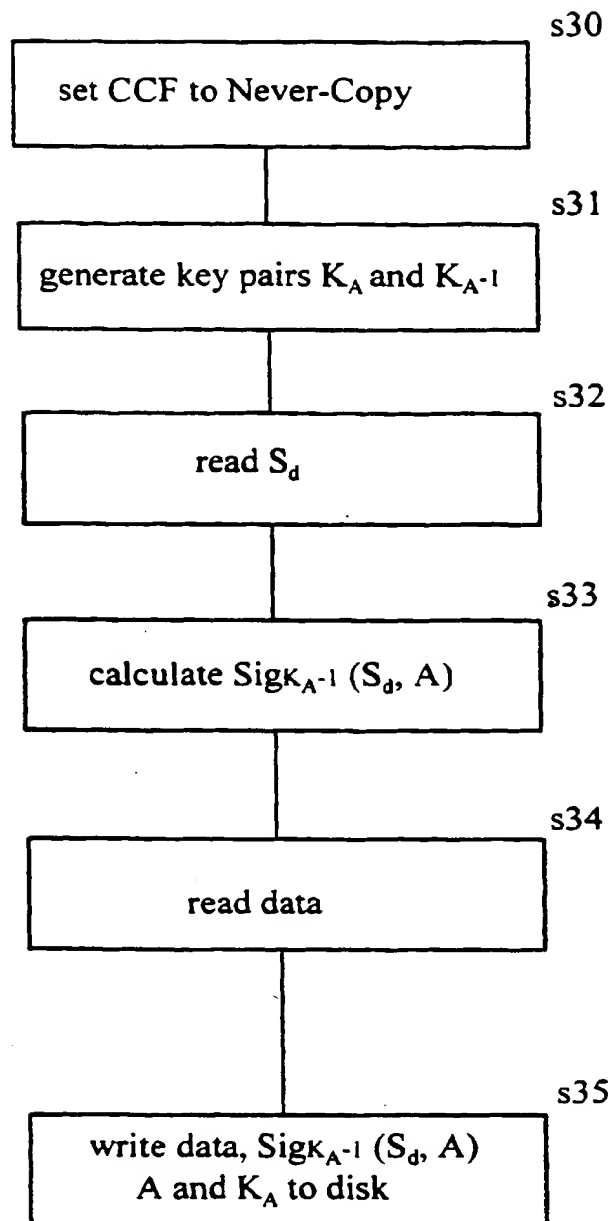


Figure 12

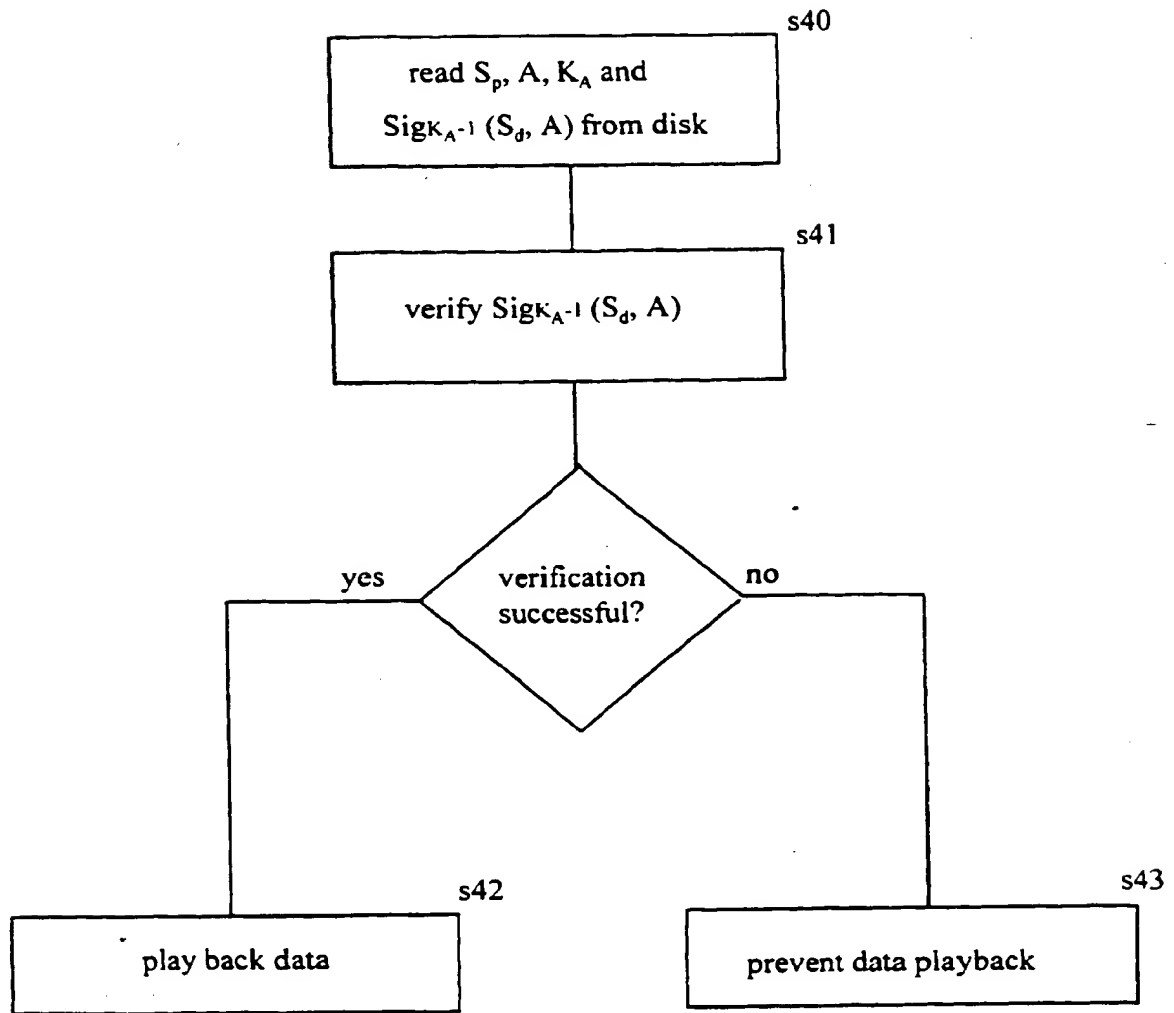


Figure 13

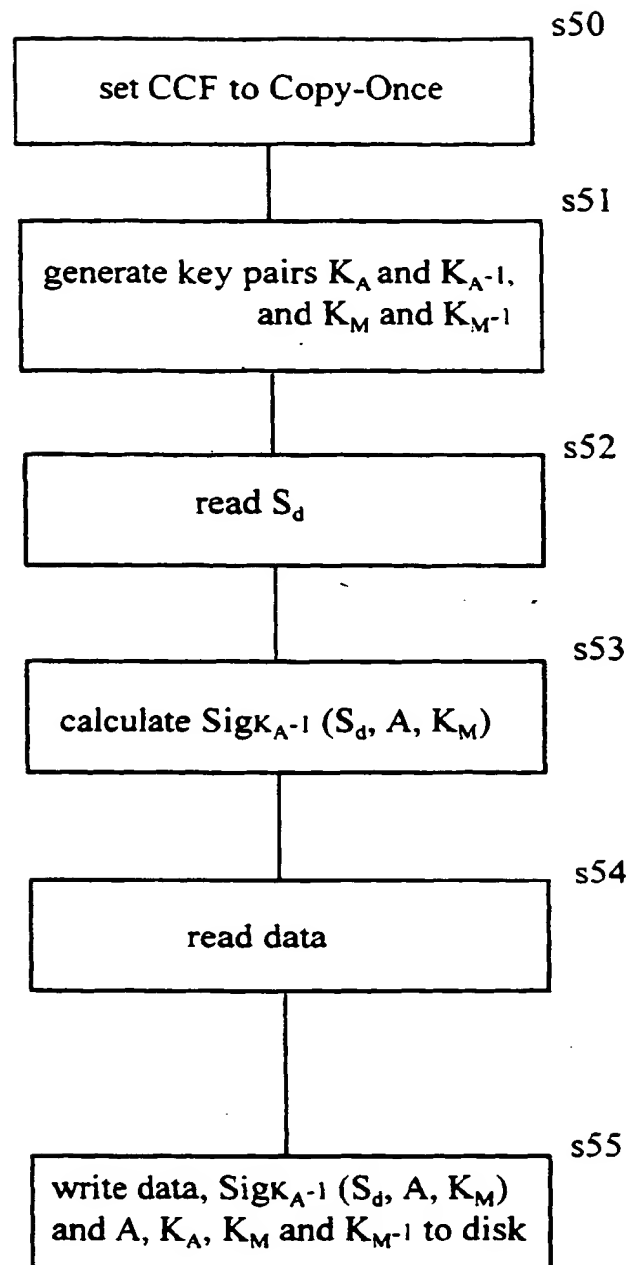


Figure 14

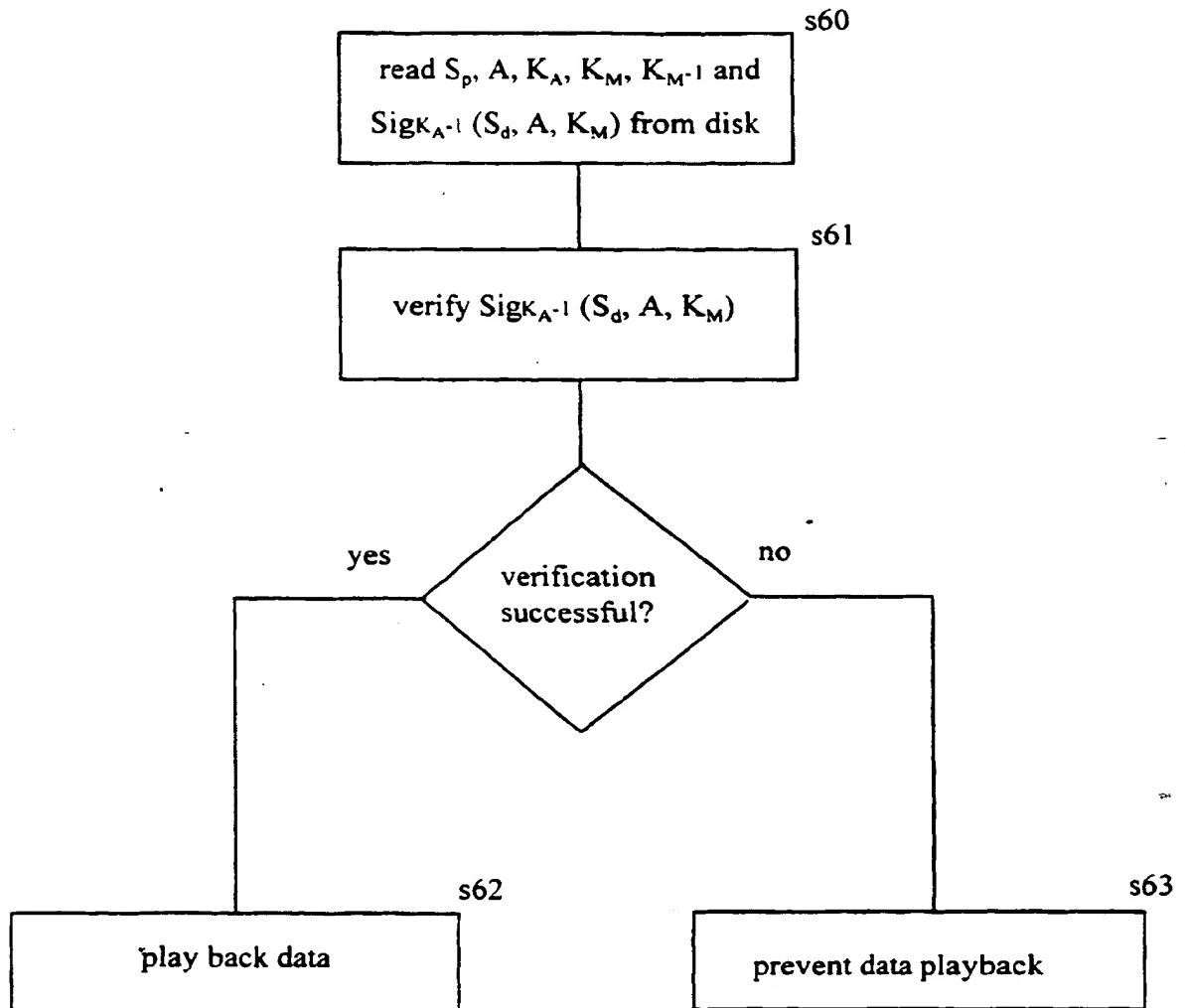


Figure 15

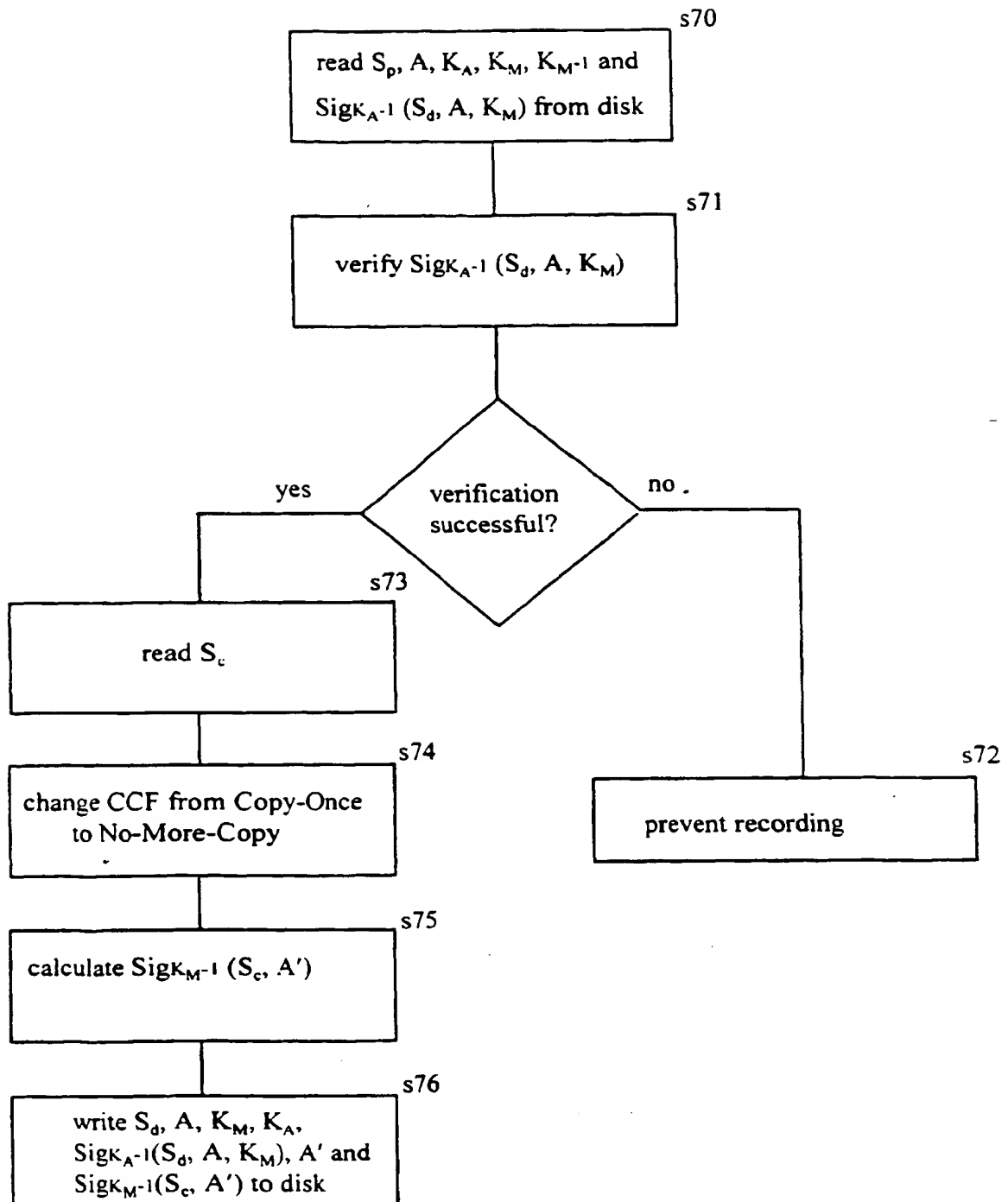


Figure 16

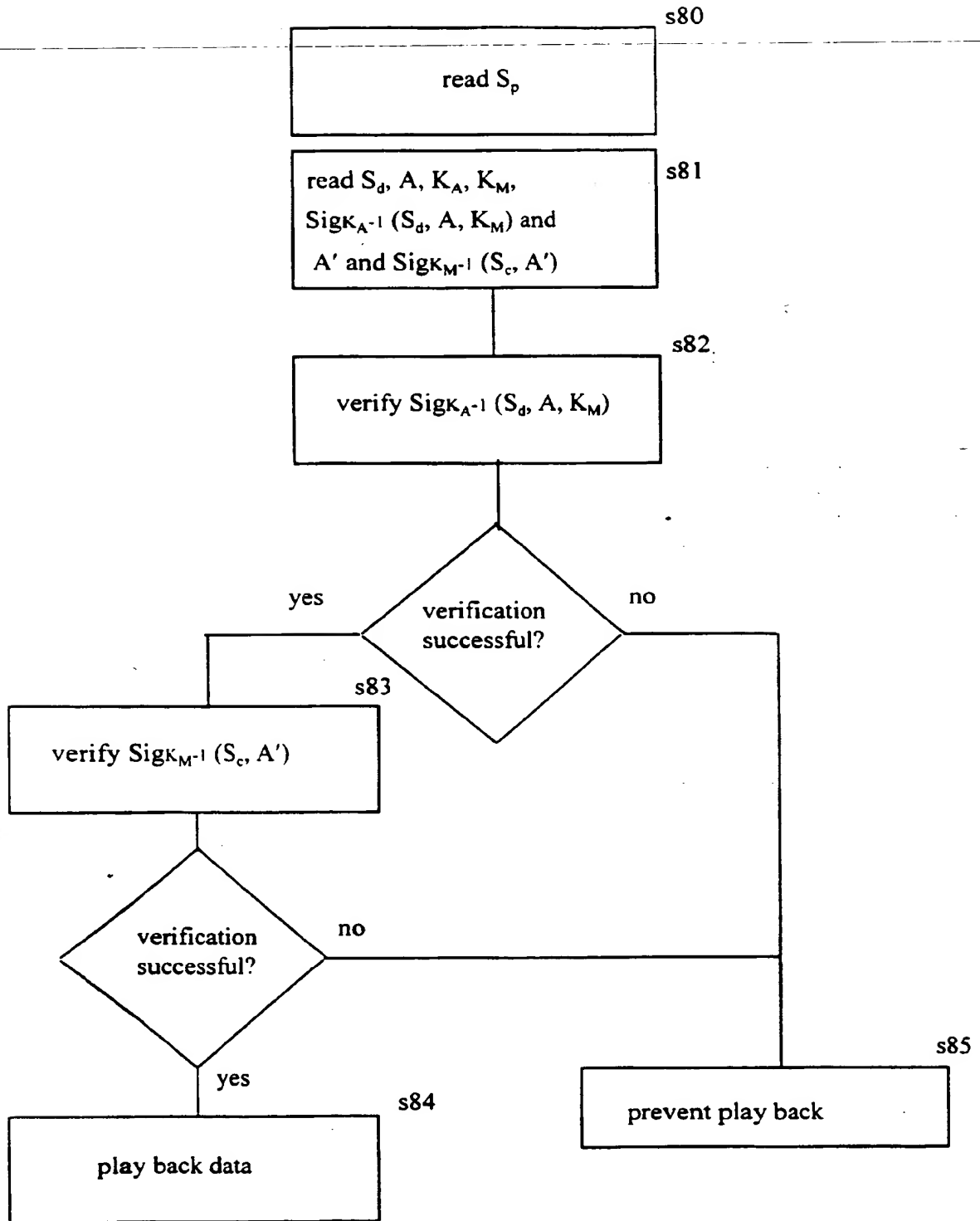


Figure 17



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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 7028

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 5 761 301 A (GOTOH YOSHIHO ET AL) 2 June 1998 * column 2, line 53 - column 4, line 42 * * column 12, line 47 - column 13, line 14; figure 41 * ---	1-8, 13-18, 20-23	G06F1/00 G11B20/00
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			G06F G11B
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 11 March 1999	Examiner Moens, R
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11-03-1999

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